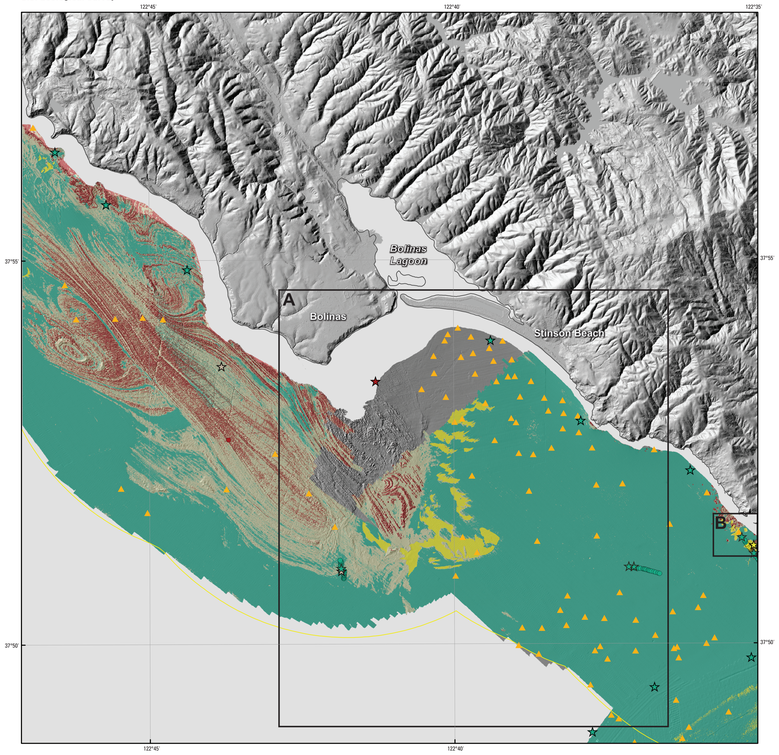
U.S. Department of the Interior
U.S. Geological Survey

Open-File Report 2015–1135
Sheet 6 of 10
Pamphlet accompanies map



Onshore elevation data collected by Earth Eye in 2010 for San Francisco State University and U.S. Geological Survey (available at http://eed.usgs.gov/). Offshore shaded-relief bathymetry from map on sheet 2, this report. California's State Waters limit from NOAA Office of Coast Survey

Universal Transverse Mercator projection, Zone 10N

NOT INTENDED FOR NAVIGATIONAL USE

APPROXIMATE MEAN DECLINATION, 2015

SCALE 1:50 000

2 0 2 MILES
7000 3500 0 7000 FEET
1 0.5 0 1 KILOMETER
ONE MILE = 0.869 NAUTICAL MILES

MAP LOCATION

Seafloor-character map simplified from map on sheet 5, this report. Video observations recorded and digital still photographs taken in 2006-2009. Sample localities from usSEABED (Reid and others, 2006)

GIS database and digital cartography by Nadine E. Golden and Elayne L. Phillips

Manuscript approved for publication July 21, 2015

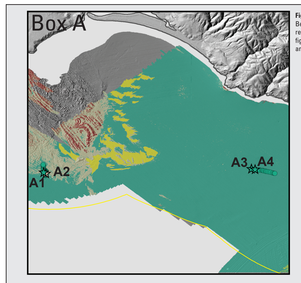


Figure 1A. View of seafloor character mapped south of Bolinas and Stinson Beach (see Box A, on map, for location), showing locations of periodic real-time video observations (dots) and digital still photographs (stars; see figs. 1B through 1E) from camera line 100 (approximately 2.5 km offshore) and camera line 102 (approximately 7 km offshore), cruise F–2–08–NC.

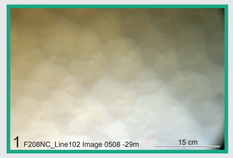


Figure 1B. Digital still photograph no. A1 from camera line 102 (see fig. 1A for location). Unconsolidated, fine- to medium-grained sand with oscillatory ripples in confused pattern (water depth, 29 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Distance between lasers (red dots) is 15 cm.

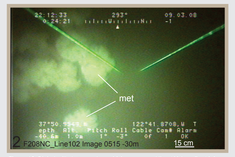


Figure 1C. Digital still photograph no. A2 from cameral line 102 (see fig. 1A for location). Mixed, smooth sediment and rock (water depth, 30 m). Abiotic complexity is low, biotic complexity is present, and biocover is moderate. Biocover includes white plumed anemones, *Metridium* spp. (met). Distance between lasers (green lines) is 15 cm.

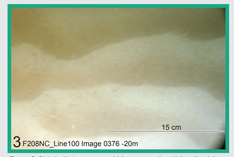


Figure 1D. Digital still photograph no. A3 from camera line 100 (see fig. 1A for location). Unconsolidated sand with oscillatory ripples (water depth, 20 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Scale determined from lasers on synchronized video (scale lasers are not visible on photograph).

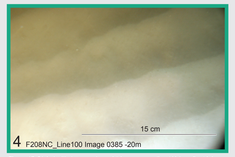


Figure 1E. Digital still photograph no. A4 from camera line 100 (see fig. 1A for location). Unconsolidated sand with oscillatory ripples (water depth, 20 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Scale determined from lasers on synchronized video (scale lasers are not visible on photograph).

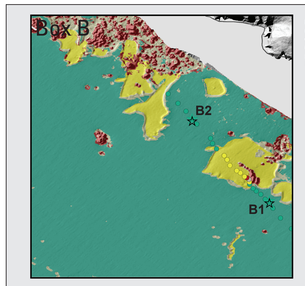


Figure 2A. Detailed view of seafloor character mapped in nearshore area southeast of Stinson Beach (see Box B, on map, for location), showing locations of periodic real-time video observations (dots) and digital still photographs (stars; see figs. 2B, 2C) from camera line 101, cruise F–2–08–NC.

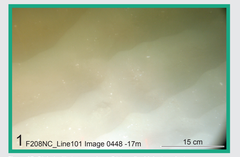


Figure 2B. Digital still photograph no. B1 (see fig. 2A for location). Unconsolidated sand with oscillatory ripples (water depth, 17 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Distance between lasers (red dots) is 15 cm.

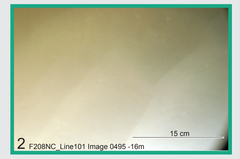


Figure 2C. Digital still photograph no. B2 (see fig. 2A for location). Unconsolidated sand with oscillatory ripples (water depth, 16 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Scale determined from lasers on synchronized video (scale lasers are not visible on photograph).

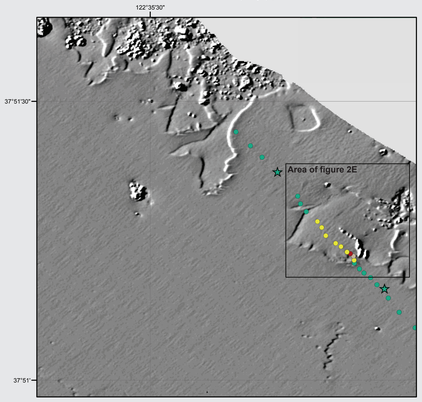


Figure 2D. Shaded-relief bathymetry of nearshore area southeast of Stinson Beach (same area as shown in fig. 2A; see Box B, on map, for location), showing scour depressions. Locations of periodic real-time video observations (dots) and digital still photographs (stars; see figs. 2B, 2C) from camera line 101, cruise F–2–08–NC, shown for reference.

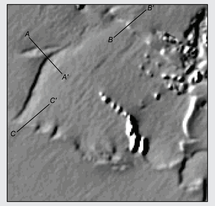


Figure 2E. Detailed view of part of shaded-relief bathymetry in figure 2D, showing locations of bathymetric profiles *A–A'*, *B–B'*, and *C–C'* (figs. 2F, 2G, and 2H, respectively), which were made along transects across boundaries of scour depression.

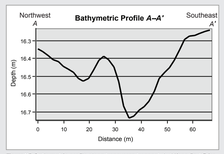


Figure 2F. Bathymetric profile along transverse transect *A–A'* (see fig. 2E for location), showing that seafloor is deepest at boundary of scour depression before rising toward center of depression.

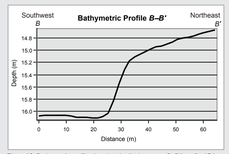


Figure 2G. Bathymetric profile along longitudinal transect *B–B'* (see fig. 2E for location), showing distinct bathymetric gradient across boundary of scour depression.

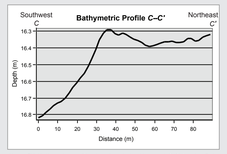


Figure 2H. Bathymetric profile along longitudinal transect *C–C'* (see fig. 2E for location), showing distinct bathymetric gradient across boundary of scour depression.

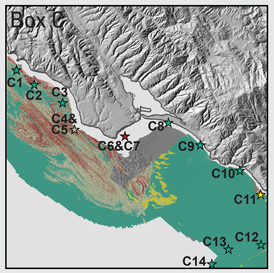


Figure 3A. View of seafloor-character map of entire Offshore of Bolinas map area, showing locations of sediment samples (stars; see figs. 3B through 3D) from U.S. Geological Survey cruise S–8–10–SF.

Figure 3B. Digital still photograph no. C1 of sediment sample OSP16 (see fig. 3A for location). Medium- to coarse-grained, grayish-black sand and some shell hash (water depth, 10 m). Scale determined from size of sediment sampler.

Figure 3C. Digital still photograph no. C2 of sediment sample OSP17 (see fig. 3A for location). Medium- to coarse-grained, grayish-black sand and shell hash (water depth, 16 m). Scale determined from size of sediment sampler.

Figure 3D. Digital still photograph no. C3 of sediment sample OSP18 (see fig. 3A for location). Fine- to medium-grained, well-sorted, dark-gray sand and sparse shell hash (water depth, 8 m). Scale determined from size of sediment sampler.

Figure 3E. Figure 3E. Digital still photograph no. C4 of large rock fragment broken off rocky reef by sediment sampler at sampling station OSP19 (see fig. 3F; see also, fig. 3A for location). Rocky reef (water depth, 15 m). Scale determined from size of hand.

Figure 3F. Digital still photograph no. C5 of sediment sample OSP19 (see fig. 3A for location). Pieces of rocky reef (see fig. 3E for close-up of large rock fragment) mixed with unconsolidated, coarse- and fine-grained sediment (water depth, 15 m). Scale determined from size of sediment sampler.

Figure 3G. Digital still photograph no. C6 of sediment sample OSP21 (see fig. 3A for location). Large, rounded cobbles (water depth, 6 m); see figure 3H for close-up. Scale determined from size of sediment sampler.

Figure 3H. Digital still photograph no. C7 of sediment sample OSP21 (see fig. 3G; see also fig. 3A for location). Large, rounded cobbles (water depth, 6 m). Scale determined from size of sample bags.

Figure 3I. Digital still photograph no. C8 of sediment sample OSP22 (see fig. 3A for location). Fine-grained, well-sorted sand (water depth, 10 m). Scale determined from size of sediment sampler.

Figure 3J. Digital still photograph no. C9 of sediment sample OSP23 (see fig. 3A for location). Fine-grained, well-sorted sand (water depth, 11 m). Scale determined from size of sediment sampler.

Figure 3K. Digital still photograph no. C10 of sediment sample OSP24 (see fig. 3A for location). Fine-grained, well-sorted sand (water depth, 11 m). Scale determined from size of sediment sampler.

Figure 3L. Digital still photograph no. C11 of sediment sample OSP25 (see fig. 3A for location). Coarse-grained, black sand and shell hash (water depth, 17 m). Scale determined from size of sediment sampler.

Figure 3M. Digital still photograph no. C12 of sediment sample BRP03 (see fig. 3A for location). Fine-grained, well-sorted sand and sparse shell hash (water depth, 12 m). Scale determined from size of sediment sampler.

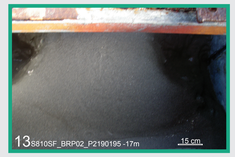


Figure 3N. Digital still photograph no. C13 of sediment sample BRP02 (see fig. 3A for location). Fine-grained, well-sorted sand (water depth, 17 m). Scale determined from size of sediment sampler.

Figure 3O. Digital still photograph no. C14 of sediment sample BRP01 (see fig. 3A for location). Fine-grained, well-sorted sand (water depth, 18 m). Scale determined from size of sediment sampler.

DISCUSSION

Between 2004 and 2010, the seafloor in the Offshore of Bolinas map area was mapped by Fugro Pelagos, by California State University, Monterey Bay (CSUMB), and by Moss Landing Marine Laboratories, using multibeam echosounders, bathymetric sidescan-sonar units, and interferometric systems (see sheets 1, 2, 3). These mapping missions combined to collect bathymetry and acoustic-backscatter data from about the 10-m isobath to out beyond the 3-nautical-mile limit of California's State Waters. In order to characterize the bathymetry and acoustic-backscatter data into geologically and biologically useful information, the U.S. Geological Survey (USGS) ground-truth-surveyed the data by towing a camera sled (fig. 4) over specific locations throughout the map area in 2008.

During the ground-truth-survey cruise, the camera sled was towed 1 to 2 m above the seafloor, at speeds of between 1 and 2 nautical miles/hour. The sled housed two standard-definition (640×480 pixel resolution) video cameras (one forward looking, the other downward looking), a high-definition (1,080×1,920 pixel resolution) video camera, and an 8-megapixel digital still camera, which captured a digital still photograph once every 30 seconds. The video was relayed in real time to the research vessel, where USGS and National Oceanic and Atmospheric Administration (NOAA) scientists recorded both the geologic and biologic character of the seafloor once every minute, using programmable keypads. The locations and directions of the camera-sled tracklines were chosen in order to visually inspect areas thought to represent the full range of bottom hardness and rugosity in the map area.

In the context of marine-fisheries management, benthic-habitat complexity can be divided into abiotic (geologic) and biotic (biologic) components. Benthic-habitat complexity refers to the visual classification of local abiotic and biotic vertical relief and structure that may provide potential refuge for both juvenile and adult forms of various species. Only abiotic attributes (primary- and secondary-substrate composition) were used in the production of the seafloor-character map on sheet 5. Classifications of primary and secondary substrate are based on the Wentworth (1922) scale of sediment grain-size categories, and the sand, cobble, and boulder sizes are classified as in Wentworth (1922). However, the difficulty in distinguishing the finest divisions in the Wentworth (1922) scale during video observations made it necessary to aggregate some grain-size classes: the granule and pebble sizes have been grouped together into a class called "gravel," and the clay and silt sizes have been grouped into a class called "mud." In addition, hard bottom and clasts larger than boulder size are classified as "rock." Primary and secondary substrate, by definition, constitute greater than 50 and 20 percent of the seafloor during an observation, respectively.

This sheet contains a smaller, simplified (depth-zone symbology has been removed) version of the seafloor-character map (sheet 5), on which the camera-sled tracklines used to ground-truth-survey the sonar data are indicated by aligned colored dots, each dot representing the location of a recorded observation. Primary- and secondary-substrate compositions are shown by differently colored dots. The map also shows the locations of the detailed views of seafloor character along some of the tracklines (Boxes A, B) that are highlighted on this sheet (figs. 1A, 2A); note that the location of Box C (fig. 3A), which shows sediment-sample localities from USGS cruise S–8–10–SF, is not shown because it covers the entire Offshore of Bolinas map area. Also shown are locations of samples (triangles) from usSEABED (Reid and others, 2006) that were used to supplement the ground-truth surveys.

The seafloor-character map shows that the Offshore of Bolinas map area is dominated by sandy sediment (see, for example, figs 1B, 1D, 1E, 2B, 2C), which is characterized by sharp-crested, oscillatory ripples (typical wavelengths, 5 to 15 cm). The sandy-shelf areas are typified by low abiotic complexity, low biotic complexity, and low biocover.

In the shallow areas south and west of the Bolinas headland, rocky outcrops and areas of moderately to poorly sorted, coarse sand and gravel are present, and they make up the dominant substrate in this part of the map area. These areas are characterized by moderate to high abiotic complexity created by steep, rocky outcrops that project dramatically above the adjacent sandy seafloor. Here, epifauna can be diverse, and urchins, starfish (asteroids), and schools of rockfish, as well as numerous attached forms (for example, sponges, cup corals), provide moderate to high biocover (see, for example, figs. 1C, 3E, 3F).

Scour depressions, which can be found at all water depths, are both adjacent to, and distant from, rocky areas. Moderately to poorly sorted, coarse sands and gravels located in these areas typically form shallow depressions relative to the adjacent sandy seafloor. Many depressions are characterized by large ripples and megaripples composed of coarse sand, fine gravel, and scattered shells (see, for example, figs. 1B, 1D, 1E, 3L). These features provide low abiotic complexity, low biotic complexity, and low biocover.

Detailed views in figures 1A and 2A show the locations of camera-sled tracklines (aligned colored dots), as well as of the photographs (colored stars) taken along the tracklines. These photographs, which are representative of the seafloor, are displayed with a description of the observed seafloor characteristics recorded by USGS and NOAA scientists (figs. 1B through 1E; 2B through 2C). Only primary and secondary substrates are reported, although individual photographs may show more substrate types. Organisms, when present, are labeled on the photographs. Figure 3A shows the locations (colored stars) of sediment samples collected in the field and photographed onboard the ship (figs. 3B through 3O).

Ground truth surveys in the Offshore of Bolinas map area include approximately 3 trackline kilometers of video and 28 still photographs of the seafloor, in addition to 88 seafloor observations of abiotic and biotic attributes and 13 sediment samples. A visual estimate of slope was also recorded.

GLOSSARY

Rugosity—A GIS-derived characterization of seafloor roughness, calculated as the ratio of the three-dimensional surface area of seafloor to the two-dimensional planar-base area, for each cell in the bathymetry grid.

Backscatter intensity—The amplitude of the reflected sonar signal (see sheet 3) used to infer the hardness of the bottom, determined after sonar-data processing has removed (as much as possible) the effects of water depth, angle of reflection, and bottom roughness.

Biocomplexity—The assessment of the presence or absence of biological structures that have the potential of providing shelter for fauna, determined by estimating the scale, the amount, and the morphology of biological relief (as described by Tissot and others, 2006).

Biocover—The visual estimate of the proportion of biologic cover by encrusting organisms: high, greater than 50 percent; moderate, between 50 percent and 10 percent; low, less than 10 percent.

REFERENCES CITED

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Tissot, B.N., Yoklavich, M.M., Love, M.S., York, K., and Amend, M., 2006, Benthic invertebrates that form habitat on deep banks off southern California, with special reference to deep sea coral: Fishery Bulletin, v. 104, p. 167–181.

Wentworth, C.K., 1922, A scale of grade and class terms for clastic sediments: Journal of Geology, v. 30, p. 377–392.

EXPLANATION

Substrate class

- **Fine- to medium-grained smooth sediment**—Low backscatter, low rugosity; typically mud to medium-grained sand; often rippled and (or) burrowed
- **Mixed smooth sediment and rock**—Moderate to very high backscatter, low rugosity; typically coarse-grained sand, gravel, cobbles, and bedrock
- **Rock and boulder, rugose**—High backscatter, high rugosity; typically boulders and rugose bedrock
- **Medium- to coarse-grained sediment**—Very high backscatter, low rugosity; typically medium- to coarse-grained sediment, with varying amounts of shell hash; in scour depressions

Location of real-time video observation and interpreted substrate class of seafloor

- **Fine- to medium-grained smooth sediment**—Low backscatter, low rugosity; typically mud to medium-grained sand; often rippled and (or) burrowed
- **Mixed smooth sediment and rock**—Moderate to very high backscatter, low rugosity; typically coarse-grained sand, gravel, cobbles, and bedrock
- **Rock and boulder, rugose**—High backscatter, high rugosity; typically boulders and rugose bedrock
- **Medium- to coarse-grained sediment**—Very high backscatter, low rugosity; typically medium- to coarse-grained sediment, with varying amounts of shell hash; in scour depressions

Location of digital still photograph and interpreted substrate class of seafloor—For photographs of sediment samples (figs. 3B through 3O), star shows location where sample was retrieved

- **Fine- to medium-grained smooth sediment**—Low backscatter, low rugosity; typically mud to medium-grained sand; often rippled and (or) burrowed
- **Mixed smooth sediment and rock**—Moderate to very high backscatter, low rugosity; typically coarse-grained sand, gravel, cobbles, and bedrock
- **Rock and boulder, rugose**—High backscatter, high rugosity; typically boulders and rugose bedrock
- **Medium- to coarse-grained sediment**—Very high backscatter, low rugosity; typically medium- to coarse-grained sediment, with varying amounts of shell hash; in scour depressions

Interpreted substrate class depicted in digital still photograph—Indicated by colored frame around photograph (not shown on map; shown in figures only)

- **Fine- to medium-grained smooth sediment**—Low backscatter, low rugosity; typically mud to medium-grained sand; often rippled and (or) burrowed
- **Mixed smooth sediment and rock**—Moderate to very high backscatter, low rugosity; typically coarse-grained sand, gravel, cobbles, and bedrock
- **Rock and boulder, rugose**—High backscatter, high rugosity; typically boulders and rugose bedrock
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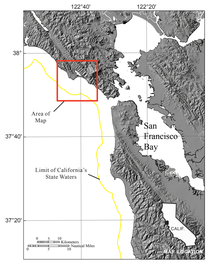
Sample localities
From usSEABED (Reid and others, 2006)

Area of "no data"—Areas near shoreline not mapped owing to insufficient high-resolution seafloor mapping data; areas beyond the 3-nautical-mile limit of California's State Waters were not mapped as part of the California Seafloor Mapping Program

3-nautical-mile limit of California's State Waters



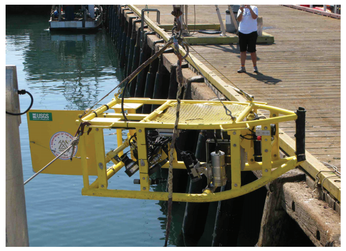


Figure 4. USGS-designed camera sled being loaded onto a research vessel in preparation for ground-truth studies. Components onboard sled include four digital video camcorders, one 8-megapixel digital SLR camera, lasers for scale, and various strobe and video lights, as well as telemetry instrumentation that records depth, altitude and compass heading.

Ground-Truth Studies, Offshore of Bolinas Map Area, California

By
Nadine E. Golden, Guy R. Cochrane, and Mercedes D. Erdey

2015

ISSN 2331-1258 (online)
https://dx.doi.org/10.3133/ofr20151135

For sale by U.S. Geological Survey, Information Services, Box 25286, Federal Center, Denver, CO 80225, 1–888–ASK–USGS

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Suggested Citation: Golden, N.E., Cochrane, G.R., and Erdey, M.D., 2015, Ground-truth studies, Offshore of Bolinas map area, California, sheet 6 of Cochrane, G.R., Dartnell, P., Johnson, S.Y., Greene, H.G., Erdey, M.D., Golden, N.E., Harwood, C.R., Endris, C.A., Manson, M.W., Sliter, R.W., Kvitek, R.G., Watt, J.T., Ross, S.L., Bruns, T.R., and Chin, J.L. (U.S. Cochrane and S.A. Cochran, eds.), California State Waters Map Series—Offshore of Bolinas, California: U.S. Geological Survey Open-File Report 2015–1135, pamphlet 36 p., 10 sheets, scale 1:24,000, http://dx.doi.org/10.3133/ofr20151135.